SEISMIC HAZARD ZONE REPORT 06

SEISMIC HAZARD ZONE REPORT FOR THE CALABASAS 7.5-MINUTE QUADRANGLE, LOS ANGELES AND VENTURA COUNTIES, CALIFORNIA

1997

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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CALIFORNIA GEOLOGICAL SURVEY'S PUBLICATION SALES OFFICES:

Southern California Regional Office
888 South Figueroa Street, Suite 475
Los Angeles, CA 90017
(213) 239-0878

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801 K Street, MS 14-31
Sacramento, CA 95814-3531
(916) 445-5716

Bay Area Regional Office
345 Middlefield Road, MS 520
Menlo Park, CA 94025
(650) 688-6327

List of Revisions – Calabasas SHZR 06	
2001	Text updated
6/29/05	BPS address corrected, web links updated, Figure 3.5 added
1/13/06	Southern California and Bay Area Regional offices address update

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EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Calabasas 7.5-minute Quadrangle, Los Angeles and Ventura counties, California. The map displays the boundaries of Zones of Required Investigation for liquefaction and earthquake-induced landslides over an area of approximately 62 square miles at a scale of 1 inch = 2,000 feet.

The urbanized eastern and southern part of the Calabasas Quadrangle lies in Los Angeles County and the rural western and northern part lies in Ventura County. The area contains parts of the cities of Los Angeles (West Hills and Woodland Hills), Calabasas, Agoura Hills, and the entire city of Hidden Hills. Also included are the unincorporated communities of Calabasas Park and Bell Canyon. The western edge of the San Fernando Valley comprises the east-central part of the quadrangle. The hilly northern and central parts of the Calabasas Quadrangle are referred to as the Simi Hills. The southern edge of the quadrangle includes the northern part of the Santa Monica Mountains. Residential and light commercial development over the past thirty years has been concentrated in the San Fernando Valley. During the past decade, development has expanded into the canyons and hilly Los Angeles County areas. Development in Ventura County has been limited mostly to the Bell Canyon area, although more development of the Ventura County portion of the quadrangle is expected.

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years.

In the Calabasas Quadrangle the liquefaction zone in Los Angeles County is primarily in Woodland Hills and other communities within western San Fernando Valley. In Ventura County the liquefaction zone is restricted almost entirely to the bottoms of Las Virgenes, Chesboro, Palo Comado and Bell canyons. In the Calabasas Quadrangle the combination of dissected hills and weak rocks has produced widespread and abundant landslides. These conditions contribute to an earthquake-induced landslide zone that covers about 27% of the quadrangle.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet page: http://www.conservation.ca.gov/CGS/index.htm

Paper copies of Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

BPS Reprographic Services
945 Bryant Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Calabasas 7.5-minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Calabasas 7.5-Minute Quadrangle, Los Angeles and Ventura Counties, California

By
Christopher J. Wills and Allan G. Barrows

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf).

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Calabasas 7.5-minute Quadrangle. This section, along with Section 2 (addressing earthquake-induced landslides), and Section 3 (addressing potential ground shaking), form a report that is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996).

Additional information on seismic hazards zone mapping in California is on DMG's Internet web page: http://www.conservation.ca.gov/CGS/index.htm

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, including areas in the Calabasas Quadrangle.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill

- Construction of shallow ground-water maps showing the historically highest known ground-water levels

- Quantitative analysis of geotechnical data to evaluate liquefaction potential of deposits

- Information on potential ground shaking intensity based on DMG probabilistic shaking maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Calabasas Quadrangle consist mainly of alluviated valleys, floodplains, and canyon regions. DMG's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Calabasas Quadrangle covers an area of about 62 square miles. The rural western and northern part of the quadrangle lies in Ventura County and the urbanized eastern and southern part of the quadrangle lies in Los Angeles County, which includes the westernmost portion of the San Fernando Valley. The project area contains parts of the cities of Los Angeles (West Hills and Woodland Hills), Calabasas, Agoura Hills, and all of the city of Hidden Hills. Also within the quadrangle are the unincorporated communities of Calabasas Park and Bell Canyon. Along the southern boundary of the quadrangle, the northern slopes of the Santa Monica Mountains descend toward the Ventura Freeway (U.S. Highway 101), which crosses the area from east to west. North of the freeway, several long, south-trending canyons (Las Virgenes, Cheseboro, and Palo Comado) divide the irregular, dissected upland terrain that rises toward the crest of the Simi Hills.

The San Fernando Valley is an east-trending structural trough within the Transverse Ranges of Southern California. The mountains that bound it to the north and south are actively deforming anticlinal ranges bounded on their south sides by thrust faults. As these ranges have risen and deformed, the San Fernando Valley has subsided and filled with sediment.

The western portion of the San Fernando Valley, including the eastern part of the Calabasas Quadrangle, has received sediment from small drainage basins that occur within the Santa Monica Mountains, Simi Hills and Santa Susana Mountains. The small streams draining these basins have deposited their sediment in the form of channel deposits, alluvial fans and floodplain deposits in the valley. Composition of the deposits depends upon the geology within the source areas of the steams. Drainage courses with source areas dominated by shale of the Modelo Formation tend to create deposits of clayey alluvium, whereas those with sources in Saugus, Chatsworth, or Topanga formations tend to deposit silty or sandy alluvium.

GEOLOGY

Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. Late Quaternary geologic units in the San Fernando Valley area were completely re-mapped for this study and a concurrent study by engineering geologist Chris Hitchcock of William Lettis and Associates (Hitchcock and Wills, 1998; 2000). Lettis and Associates received a grant from the National Science Foundation (NSF) to study the activity of the Northridge Hills uplift. As part of the research for this study, Hitchcock mapped Quaternary surficial units by interpreting their geomorphic expression on aerial photographs and topographic maps. The primary source for this work was 1938 aerial photographs taken by the U.S. Department of Agriculture (USDA). His mapping covered parts of the Canoga Park, Oat Mountain, and other quadrangles east of the Calabasas Quadrangle. Mapping was extended through the Calabasas Quadrangle for the current study using 1952 U.S.D.A. aerial photos, 1920-era topographic maps and subsurface data. The resulting map (Hitchcock and Wills, 1998; 2000) represents a cooperative effort to depict the Quaternary geology of the San Fernando Valley combining surficial geomorphic mapping and information about subsurface soil engineering properties. The portion of this map that covers the Calabasas Quadrangle is reproduced as Plate 1.1.

In preparing the Quaternary geologic map for the Calabasas Quadrangle, geologic maps prepared by Tinsley and Fumal (1985), Yerkes and Campbell (1980), Yerkes and Showalter (1993), Dibblee (1992), Weber (1984), and Irvine (1989) were referred to. A digital version of the geologic map compiled by Yerkes and Showalter (1993) was obtained from the U.S. Geological Survey (Yerkes and Campbell, 1995). For this study, we did not review or revise the mapping of bedrock units by Yerkes and Campbell (1995), except at the contacts between bedrock and Quaternary units. Within the Quaternary units, the map of Yerkes and Campbell (1995) did not subdivide the alluvium

by age or environment of deposition. Therefore, mapping for this study was needed to show the different alluvial units. For this map (Plate 1.1), geologic units were defined based on geomorphic expression of Quaternary units (interpreted from aerial photographs and historic topographic maps) and subsurface characteristics of those units (based on borehole data). This mapping was, in part, an extension of similar mapping on the adjacent Canoga Park Quadrangle, and it was facilitated by the geomorphic interpretations of C.S. Hitchcock of William Lettis and Associates. The nomenclature of the Southern California Areal Mapping Project (SCAMP) (Morton and Kennedy, 1989) was applied to all Quaternary units (Table 1.1).

	Alluvial fan deposits	**alluvial valley deposits**	
Active	Qf- active fan	Qa- active depositional basin	
	Qw- active wash		Holocene?
Young	Qyf2	Qyt	
	Qyf1		
Old	Qof2	Qt	
	Qof1		Pleistocene?
Very old	Qvof2	Qvoa2*	
		Qvoa1*	

*may have been alluvial fan, depositional form not preserved

Table 1.1. Units of the Southern California Areal Mapping Project (SCAMP) Nomenclature Used in the San Fernando Valley.

The Quaternary geologic map (Plate 1.1) shows that the Calabasas Quadrangle includes the western end of the San Fernando Valley, as well as an extensive area of uplands in the Simi Hills and Santa Monica Mountains. Within these uplands, the only Quaternary units are narrow areas of alluvium along the major stream courses. Arroyo Calabasas and several minor creeks flow into the San Fernando Valley, where they have deposited alluvial fans. The Arroyo Calabasas alluvial fan extends to the northwest onto the floor of the San Fernando Valley. The lower end of this fan nearly meets the end of the Browns Canyon fan, which extends onto the valley floor from the north in the Oat Mountain Quadrangle. The intersection of these two fans, on the Canoga Park Quadrangle just east of the Calabasas Quadrangle, may have formed a blockage in the eastward drainage of the valley. West of this blockage and extending onto the Calabasas

Quadrangle is an alluvial basin deposit that can be distinguished from the surrounding alluvial fan deposits by the characteristics of its components as determined from subsurface data.

ENGINEERING GEOLOGY

The geologic units described above were primarily mapped from their surface expression, especially geomorphology as shown on aerial photos and old topographic maps. The geomorphic mapping was compared with the subsurface properties described in over 175 borehole logs in the study area. Subsurface data used for this study includes the database compiled by John Tinsley for previous liquefaction studies (Tinsley and Fumal, 1985; Tinsley and others, 1985), a database of shear wave velocity measurements originally compiled by Walter Silva (Wills and Silva, 1996), and additional data collected for this study. Subsurface data were collected for this study at Caltrans, the California Department of Water Resources, DMG files of seismic reports for hospital and school sites, the Regional Water Quality Control Board and from Law Crandall, Inc., Leighton and Associates, Inc., and Woodward-Clyde Consultants. In general, the data gathered for geotechnical studies appear to be complete and consistent. Data from environmental geology reports filed with the Water Quality Control Board provide reliable information about water levels, but geotechnical data, particularly SPT blow counts, are sometimes less reliable due to use of non-standard equipment and incomplete reporting of procedures. Water-well logs from the Department of Water Resources tend to have very sketchy lithologic descriptions and generally unreliable reports of shallow, unconfined water levels. Apparently, water-well drillers occasionally note the level of "productive water," ignoring shallower perched water or water in less permeable layers.

Standard Penetration Test (SPT) data provide a standardized measure of the penetration resistance of a geologic deposit and commonly are used as an index of density. Many geotechnical investigations record SPT data, including the number of blows by a 140-pound drop weight required to drive a sampler of specific dimensions one foot into the soil. Recorded blow counts for non-SPT geotechnical sampling, where the sampler diameter, hammer weight or drop distance differ from those specified for an SPT (ASTM D1586), were converted to SPT-equivalent blow count values and entered into the DMG GIS. The actual and converted SPT blow counts were normalized to a common reference effective overburden pressure of 1 atmosphere (approximately 1 ton per square foot) and a hammer efficiency of 60% using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

Data from previous databases and additional borehole logs were entered into the DMG GIS database. Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2. Construction of cross sections from the borehole logs, using the GIS, enabled the correlation of soil types from one borehole to another and the outlining of areas of similar soils.

In most cases, the subsurface data allow mapping of different alluvial fans. Different generations of alluvium on the same fan, which are very apparent from the geomorphology, are not distinguishable from the subsurface data.

The subsurface data were particularly valuable in mapping the basin or flood plain deposits (Qa). On previous maps, these deposits had been mapped as part of the adjoining alluvial fans. Geomorphically, they appear to be the lower parts of alluvial fans. Borehole data show that in the subsurface, however, the alluvial fan deposits are composed of layers of silt, silty sand, and clay, which are not easily correlatable between boreholes. The flood plain deposits, in contrast, are composed mainly of clay, and, therefore, could most easily be distinguished using the subsurface data.

Descriptions of characteristics of geologic units recorded on the borehole logs are given below. These descriptions are generalized but give the most commonly encountered characteristics of the unit (see Table 1.2).

Younger alluvium (Qyf2, Qw)

Within an alluvial fan, the different generations of younger alluvium can be distinguished by their geomorphic relationships. In the subsurface, it is not possible to distinguish among the generations on an alluvial fan. There may simply be too little difference in age among these units, which probably range from mid-Holocene to historic, for any differences in density or cementation to have formed.

In the Calabasas Quadrangle, only the Arroyo Calabasas fan has distinguishable subunits of different ages. In the subsurface, all of the generations of fan deposits consist of clay and silt with interbeds of sand and silty sand. The sand layers are generally described as medium to coarse sand and are sometimes "pebbly." Field SPT N values of granular deposits are typically between 10 and 20. The young Arroyo Calabasas fan appears to be a thin deposit. Logs from some boreholes in this fan describe a reddish brown (or "gray-orange") dense to very dense sand with gravel at 15 to 25 feet below the surface.

In the canyons within the upland areas, only the active or very young alluvium is preserved. The subsurface characteristics of this alluvium are dependent on the bedrock type in the watershed of each stream. A few small stream valleys in the Hidden Hills area (Long Valley and several smaller valleys west of it) have only Modelo Formation shale in the watershed. Alluvium in these valleys is shown as exclusively clay on logs from boreholes that we have obtained. In the larger valleys (Palo Comado, Cheseboro, and Las Virgenes canyons to the west and Bell Canyon to the north) the bedrock in the watershed is more varied. Consequently, the alluvium is also more varied in grain size. The borehole logs, obtained from these valleys, show generally silty sand and silty clay alluvium.

Geologic Map Unit	Material Type	Consistency	Liquefaction Susceptibility
Qa, alluvial basin (floodplain)	clay, silty clay	soft/loose	low
Qw, stream channels	silty sand, sandy silt	loose-moderately dense	high, locally low
Qyf2, younger alluvial fans	silty sand, sand, minor clay	loose-moderately dense	high

Table 1.2. General Geotechnical Characteristics and Liquefaction Susceptibility of Younger Quaternary Units.

GROUND-WATER CONDITIONS

Liquefaction hazard may exist in areas where depth to ground water is 40 feet or less. DMG uses the highest known ground-water levels because water levels during an earthquake cannot be anticipated because of the unpredictable fluctuations caused by natural processes and human activities. A historical-high ground-water map differs from most ground-water maps, which show the actual water table at a particular time. Plate 1.2 depicts a hypothetical ground-water table within alluviated areas.

Ground-water conditions were investigated in the Calabasas Quadrangle to evaluate the depth to saturated materials. Saturated conditions reduce the effective normal stress, thereby increasing the likelihood of earthquake-induced liquefaction (Youd, 1973). The evaluation was based on first-encountered water noted in geotechnical borehole logs. The depths to first-encountered unconfined ground water were plotted onto a map of the project area to constrain the estimate of historically shallowest ground water. Water depths from boreholes known to penetrate confined aquifers were not utilized.

The San Fernando Valley ground-water basin is a major source of domestic water for the City of Los Angeles and, as a result, has been extensively studied. The legal rights to water in the ground within the San Fernando Valley were the subject of a lawsuit by the City of Los Angeles against the City of San Fernando and other operators of water wells in the basin. The "Report of Referee" (California State Water Rights Board, 1962) contains information on the geology, soils and ground-water levels of the San Fernando Valley.

The Report of Referee shows that ground water reached its highest levels in 1944, before excessive pumping caused drawdowns throughout the basin. Management of the ground-water resources led to stabilizing of ground-water elevations in the 1960's and, in some cases, rise of ground-water elevations in the 1970's and 1980's to levels approaching those of 1944. Wells monitored by the Upper Los Angeles River Watermaster (Blevins, 1995) show that in the western San Fernando Valley, including the Calabasas Quadrangle, water levels have not recovered to the levels of the 1940's.

In order to consider the historically highest ground-water level in liquefaction analysis, the 1944 ground-water elevation contours (California State Water Rights Board 1962, Plate 29) were digitized. A three-dimensional model was created from the digitized contours giving a ground-water elevation at any point on a grid. The ground-water elevation values in this grid were then subtracted from the surface elevation values from the USGS Digital Elevation Model (DEM) for the Calabasas and, nearby, Canoga Park, Oat Mountain and Van Nuys quadrangles. The difference between the surface elevation and the ground-water elevation is the ground-water depth. Subtracting the ground-water elevation grid from the DEM results in a grid of ground-water depth values at any point where the grids overlapped.

The resulting grid of ground-water depth values shows several artifacts of the differences between the sources of ground-water elevation data and surface elevation data. The ground-water elevations were interpreted from relatively few measurements in water wells. The USGS DEM is a much more detailed depiction of surface elevation; it also shows man-made features such as excavations and fills that have changed the surface elevations. Most of these surface changes occurred after the ground-water levels were measured in 1944. The ground-water depth contours were smoothed and obvious artifacts removed to create the final ground-water depth map (Plate 1.2).

In general, the final ground-water depth map shows shallow ground water in the western part of the San Fernando Valley covered by the Calabasas Quadrangle. The 1944 ground-water contours were only prepared for the San Fernando Valley. For canyons in the Simi Hills and Santa Monica Mountains, we compiled ground-water levels from geotechnical borehole logs and water wells. Ground water is shown to be relatively shallow in all canyons where records were obtained, but these data are not extensive enough to generate a ground-water contour map. In general, it appears that relatively shallow and impermeable bedrock underlying the canyon alluvium helps to maintain a shallow water table. Cheseboro Canyon may be an exception to this rule. Several water wells in that canyon encountered ground water at 50 to 75 ft. Boreholes for ground-water contamination investigations near the junction of Palo Comado and Cheseboro Canyons,

however, recorded water at 11 and 28 ft. It is most likely that ground water is shallow in this canyon as well, but the shallow ground water was not considered important or productive enough to be noted by the water-well driller.

PART II

LIQUEFACTION POTENTIAL

Liquefaction may occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. This method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the State Mining and Geology Board (DOC, 2000).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps. DMG's qualitative susceptible soil inventory is summarized below and on Table 1.2.

Younger alluvium (Qyf2, Qf, Qw)

Younger alluvium of the alluvial fans in the west end of the San Fernando Valley on the Calabasas Quadrangle consists of silty sand and sandy silt with sand, silt and clay. Most boreholes in these units contain loose to moderately dense sand or silty sand. Ground water is within 40 feet of the surface in this area so liquefaction susceptibility of these units is high.

In the large upland valleys west of the San Fernando Valley (Palo Comado, Cheseboro, and Las Virgenes canyons) the alluvium consists of clay and silt with layers of silty sand and sand. Boreholes near the edges of the alluvial deposits appear to contain more clay, possibly representing colluvium or debris flow deposits. Boreholes near stream channels appear to contain a higher proportion of sand. Unfortunately, we were not able to acquire enough borehole logs to delineate these differences. Because ground water in all the canyons has been recorded within 15 to 20 feet of the surface, overall liquefaction susceptibility of these deposits is considered to be moderate to high.

Smaller upland valleys in the Hidden Hills area have watersheds entirely underlain by Modelo Formation bedrock. As a consequence, alluvium in these valleys is clayey, and is considered to have a low susceptibility to liquefaction.

Alluvial basin or flood plain deposits (Qa)

Alluvial basin deposits consist of clay with some silt and sandy clay. This unit is within an area of shallow ground water. Despite the shallow ground water, the clay deposits are considered to have low liquefaction susceptibility.

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment

of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in DMG's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Calabasas Quadrangle, a peak acceleration of 0.60 g, resulting from an earthquake of magnitude 6.5, was used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen,1996). See the ground motion section (3) of this report for further details.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and others, 1985; National Research Council, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. DMG uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site related structures. For a regional assessment DMG normally has a range of FS that results from the liquefaction analyses. The DMG liquefaction analysis program calculates an FS at each sample that has blow counts. The lowest FS in each borehole is used for that location. These FS vary in reliability according to the quality of the geotechnical data. These FS as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil are evaluated in order to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation**.**

Of the more than 175 geotechnical borehole logs reviewed in this study (Plate 1.2), only 25 include blow-count data from SPT's or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using logged density, moisture, and sieve test values or using average test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes

2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable

4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Calabasas Quadrangle is summarized below.

Areas of Past Liquefaction

Evidence of liquefaction was recorded in the Calabasas Quadrangle following the 1994 Northridge earthquake. At a shopping center in Woodland Hills, in the Calabasas Quadrangle (Locality 1, Plate 1.1), up to 4.5 inches of differential settlement was recorded through a structure and a parking lot. This differential settlement is related to loose to moderately dense sands that underlie compacted fill at the site. Liquefaction

caused compaction of the loose sands and lateral spreading toward the drainage channel of Dry Creek, which is adjacent to the shopping center (Diaz Yourman and Associates, 1994). The loose soils were densified by compaction grouting to mitigate the liquefaction hazard (Hayward Baker, Inc., 1995).

Artificial Fills

In the Calabasas Quadrangle, no artificial fills are shown on the geologic map of Yerkes and Campbell (1995), nor were any mapped for this study, which used mainly historic aerial photos and topographic maps. Artificial fills exist along U.S. Highway 101 but are too thin to have an impact on liquefaction hazard and so were not investigated.

Areas with Sufficient Existing Geotechnical Data

Younger alluvial fan deposits (Qyf2) in the western San Fernando Valley have high liquefaction susceptibility due to high ground water and loose to moderately dense sandy materials. All of these deposits have been included in the Liquefaction Zones.

Younger alluvial stream channel deposits (Qw) mapped in southward-draining canyons contain areas of high and moderate liquefaction susceptibility. Because the amount of subsurface data does not allow us to subdivide this geologic unit, all of this alluvium has been included in the Liquefaction Zones.

Younger alluvial basin deposits (Qa) in the western San Fernando Valley have low liquefaction susceptibility despite high ground water because they consist of clayey materials. These deposits have not been included in the Liquefaction Zones.

Areas with Insufficient Existing Geotechnical Data

Younger alluvial stream channel deposits (Qw) mapped in the upper portions of southward-draining canyons (Palo Comado, Cheseboro, and Las Virgenes Canyons) and in Bell Canyon, which drains eastward into the San Fernando Valley, have no geotechnical borehole information. It was assumed, in these cases, that the material characteristics and ground water conditions are similar to Qw deposits where subsurface information is available, and these deposits are included in the liquefaction zones.

We found no borehole logs for the area mapped as older alluvial terrace deposits (Qt) in the Calabasas area. In boreholes adjacent to this area, dense sand and sandy clay were encountered at depth. These materials may represent the older material that crops out nearby. Assuming that is the case, the dense granular deposits have low liquefaction susceptibility. These deposits have not been included in the liquefaction zones.

ACKNOWLEDGMENTS

The authors would like to thank the staff at the California Department of Transportation (Caltrans), and the Los Angeles Regional Water Quality Control Board for their

assistance in the collection of subsurface borehole data. Marshall Lew of Law-Crandall, Inc. and Bruce Clark at Leighton and Associates generously provided access to pertinent report files at their firms. John Tinsley of the U.S. Geological Survey graciously shared information from his extensive files of subsurface geotechnical data for this area. This study benefited from the detailed geomorphic mapping and interpretations of Quaternary surficial deposits by Chris Hitchcock of William Lettis and Associates in the adjacent Canoga Park Quadrangle. At DMG, special thanks to Bob Moskovitz, Teri McGuire, Barbara Wanish, and Scott Shepherd for their GIS operations support, and to Joy Arthur for designing and plotting the graphic displays associated with the liquefaction zone map and this report.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Calabasas 7.5-Minute Quadrangle, Los Angeles and Ventura Counties, California

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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf).

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Calabasas 7.5-minute Quadrangle. This section, along with Section 1 (addressing liquefaction), and Section 3 (addressing earthquake shaking), form a report that is one of a series that summarizes the preparation of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic

hazard zone mapping in California can be accessed on DMG's Internet web page: http://www.conservation.ca.gov/CGS/index.htm

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by loose, weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the Calabasas Quadrangle.

METHODS SUMMARY

The mapping of earthquake-induced landslide hazard zones presented in this report is based on the best available terrain, geologic, geotechnical, and seismological data. If unavailable or significantly outdated, new forms of these data were compiled or generated specifically for this project. The following were collected or generated for this evaluation:

- Digital terrain data were used to provide an up-to-date representation of slope gradient and slope aspect in the study area
- Geologic mapping was used to provide an accurate representation of the spatial distribution of geologic materials in the study area. In addition, a map of existing landslides, whether triggered by earthquakes or not, was prepared
- Geotechnical laboratory test data were collected and statistically analyzed to quantitatively characterize the strength properties and dynamic slope stability of geologic materials in the study area
- Seismological data in the form of DMG probabilistic shaking maps and catalogs of strong-motion records were used to characterize future earthquake shaking within the mapped area

The data collected for this evaluation were processed into a series of GIS layers using commercially available software. A slope stability analysis was performed using the Newmark method of analysis (Newmark, 1965), resulting in a map of landslide hazard potential. The earthquake-induced landslide hazard zone was derived from the landslide

hazard potential map according to criteria developed in a DMG pilot study (McCrink and Real, 1996) and adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Calabasas Quadrangle, for more information on the delineation of liquefaction zones.

The remainder of this report describes in more detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the Calabasas Quadrangle. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone maps.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Calabasas Quadrangle covers an area of about 62 square miles. The rural western and northern part of the quadrangle lies in Ventura County and the urbanized eastern and southern part of the quadrangle lies in Los Angeles County, which includes the westernmost portion of the San Fernando Valley. The project area contains parts of the

cities of Los Angeles (West Hills and Woodland Hills), Calabasas, Agoura Hills, and the entire city of Hidden Hills. Also within the quadrangle are the unincorporated communities of Calabasas Park and Bell Canyon. The western edge of the San Fernando Valley comprises the east-central part of the Calabasas Quadrangle. The hilly northern and central parts of the Calabasas Quadrangle are referred to as the Simi Hills, and the southern edge of the quadrangle includes the northerly edge of the Santa Monica Mountains. Drainage is largely to the south in Palo Comado, Cheseboro, and Las Virgenes canyons, and to the east in Bell Canyon. The northwest corner of the quadrangle drains north into Simi Valley via Runkle and Meier canyons. Elevations range from 2289 feet in the northwesterly portion of the quadrangle, to 695 feet in Las Virgenes Canyon at the south-central edge.

Residential and light commercial development over the past thirty years has been concentrated in the flat-lying areas of the San Fernando Valley. During the past decade, development has expanded into the canyons and hilly areas of the Calabasas Quadrangle that lie within Los Angeles County. Development in Ventura County has been limited mostly to the Bell Canyon area, although there are, at present, plans to develop more of the Ventura County portion of the quadrangle.

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface. Within the Calabasas Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle topographic contours that are based on 1947 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

To update the terrain data, areas that have recently undergone large-scale grading in the hilly portions of the Calabasas Quadrangle were identified on aerial photography flown in the winter and spring of 1994 (see Plate 2.1). Terrain data for these areas were obtained from an airborne interferometric radar (TOPSAR) DEM flown and processed in August 1994 by NASA's Jet Propulsion Laboratory (JPL), and reprocessed by Calgis, Inc. (GeoSAR Consortium, 1995; 1996). The terrain data were also smoothed and filtered prior to analysis.

A slope map was made from the DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The DEM was also used to make a slope aspect map. The manner in which the slope and aspect maps were used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

For the Calabasas Quadrangle, a recently compiled geologic map (Yerkes and Showalter, 1993) was obtained from the U.S. Geological Survey (USGS) in digital form (Yerkes and Campbell, 1995). In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of landslides was noted.

The oldest geologic unit mapped in the Calabasas Quadrangle is the Upper Cretaceous Chatsworth Formation (Yerkes and Showalter map symbol Kc), which forms spectacular tilted outcrops in the northern third of the quadrangle. This formation consists of well-cemented, thick-bedded, arkosic marine sandstone and minor conglomerate interbedded with thin-bedded siltstone and mudstone.

In the northwest quarter of the quadrangle, the Chatsworth Formation is overlain by a sequence of lower Tertiary marine and non-marine clastic rocks. This sequence includes the Paleocene Simi Conglomerate (non-marine to marine, weakly to moderately indurated, clast-supported conglomerate with discontinuous lenses of sandstone and minor mudrock; Tsc) and Las Virgenes Sandstone (non-marine, weakly to moderately indurated sandstone and mudstone; Tlv), the upper Paleocene to lower Eocene Santa Susana Formation (marine, very fine- to medium-grained, moderately to well-indurated sandstone, minor conglomerate, fossiliferous concretionary sandstone, and thin-bedded siltstone; Tss), and the lower to middle Eocene Llajas Formation (marine silty sandstone and siltstone and non-marine to shallow-marine conglomerate; Tl).

In the west-central and northeast quarter of the map, the Chatsworth Formation is disconformably overlain by marine clastic and biogenic rocks of the middle Miocene Topanga Group and upper Miocene Modelo Formation. The Topanga Group consists of thick-bedded marine sandstone, siltstone, and pebbly sandstone of the Cold Creek Member (Ttcc), andesitic/dacitic flow breccia (Tcab) and basaltic flows (Tc) of the Conejo Volcanics, and semi-friable marine sandstone, siltstone, and pebble conglomerate of the Calabasas Formation (Ttc). The Modelo Formation is the most widely exposed bedrock unit in the quadrangle and is composed of interbedded deep-marine clay shale, siltstone, and sandstone (Tm), diatomaceous shale and fine sandstone (Tmd), massive, fine- to medium-grained sandstone (Tms), burnt shale (shale and siltstone altered by underground fires to slag and scoriaceous-like material, Tmb), and conglomerate and pebbly sandstone (Tmc). Upper Miocene and lower Pliocene Towsley Formation (marine sandstone, minor siltstone and shale; Tto) crops out near the center of the map.

Quaternary surficial deposits cover the floor and margins of the San Fernando Valley in the eastern part of the quadrangle and are also present in the larger canyons that drain the Simi Hills and Santa Monica Mountains. They are composed of Pleistocene and Holocene alluvial fan and basin deposits (Qa, Qw, Qvoa, and Qyf2). Landslides (Qls and Qls?) are widespread in the central and southern portions of the Calabasas Quadrangle, primarily in the tightly folded weaker members of the Modelo Formation.

Unconsolidated silt and clayey-silt deposits (res) are mapped in the dry bed of Chatsworth Reservoir. Also mapped in some areas are modern, artificial (man-made) fills (af). A more detailed discussion of the Quaternary deposits in the Calabasas Quadrangle can be found in Section 1.

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in the Calabasas Quadrangle was prepared (Irvine, 1997) by using previous work done in the area (Irvine, 1990 and Weber, 1984) and by combining field observations, analysis of aerial photos, and interpretation of landforms on current and older topographic maps. The following aerial photos were used for landslide interpretation (see Air Photos in References): NASA (1994a and b), PACWAS (1988), PACWAS (1978), USDA (1952/53), and USGS (1994). Also consulted during the mapping process were previous maps and reports that contain geologic and landslide data (Dibblee, 1992; Harp and Jibson, 1995; LA Dept. of Public Works, 1963; Weber and others, 1973; Weber, 1984; and Yerkes, 1993). Landslides were mapped and digitized at a scale of 1:24,000. For each landslide included on the map a number of characteristics (attributes) were compiled. These characteristics include the confidence of interpretation (definite, probable and questionable) and other properties, such as activity, thickness, and associated geologic unit(s). Landslides rated as definite and probable were carried into the slope stability analysis. Landslides rated as questionable were not carried into the slope stability analysis due to the uncertainty of their existence. The completed hand-drawn landslide map was scanned, digitized, and the attributes were compiled in a database. A version of this landslide inventory is included with Plate 2.1.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for rock shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Geotechnical and engineering geologic reports contained in Environmental Impact Reports and Hospital Review Project files at DMG are an additional source. Other sources include reports published in professional journals, and summaries of "state of the practice" values for some widespread formations in the region provided by practicing professionals and local government geologists. The locations of rock and soil samples taken for shear Shear-strength data for the rock units identified on the Calabasas Quadrangle geologic map were obtained from a variety of sources (see Appendix A). The locations of rock and soil samples taken for shear testing by consultants are shown on Plate 2.1.

Shear strength data gathered from the above sources were compiled for each geologic map unit. Geologic units were grouped on the basis of average angle of internal friction

(average phi) and lithologic character. Average (mean and median) phi values for each geologic map unit and corresponding strength group are summarized in Table 2.1. For most of the geologic strength groups in the map area, a single shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Tables 2.1 and 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

The results of the grouping of geologic materials in the Calabasas Quadrangle are in Tables 2.1 and 2.2.

CALABASAS QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	Kc(fbc)	21	35/36	36/37	753/525	Tsc	37
	Tto(fbc)	2	37/37				
GROUP 2	Tms(fbc)	9	36/34	33/33	457/400	Tl(fbc), Tmc(fbc)	33
	Ttc(fbc)	19	32/33			Ttcc(fbc), Tss(fbc)	
	Tc	7	32/33			Tcab, Tlv(fbc)	
GROUP 3	Kc(abc)	38	29/31	28/28	582/450		28
	Tm(fbc)	139	28/28				
	Tmd (fbc)	8	28/31			Tmb(fbc)	
	Ttc(abc)	20	29/30			Ttcc(abc)	
	Quat.(Qa, Qw, Qyf1, Qyf2)	84	26/25			af	
GROUP 4	Tm(abc)	6	22/19	20/20	417/321	Tl(abc),Tss(abc)	20
	Tmd(abc)	9	21/22			Tlv(abc)	
	Tms(abc)	4	17/18			Tmb(abc)	
	Tto(abc)	1	18/18			Tmc(abc)	
GROUP 5	Qls	6	13/10	13/10	217/181		10

Table 2.1. Summary of the Shear Strength Statistics for the Calabasas Quadrangle.

SHEAR STRENGTH GROUPS FOR THE CALABASAS QUADRANGLE

GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
Kc(fbc)	Tms(fbc)	Qt	Tm(abc)	Qls
Tto(fbc)	Ttc(fbc)	Qal	Tmb(abc)	Qls?
Tsc	Tc	Qao	Tmc(abc)	
	Tl(fbc)	Qay	Tmd(abc)	
	Ttcc(fbc)	Kc(abc)	Tms(abc)	
	Tss(fbc)	Tm(fbc)	Tto(abc)	
	Tcab	Tmd(fbc)	Tl(abc)	
	Tlv(fbc)	Tmb(fbc)	Tss(abc)	
	Tmc(fbc)	Ttc(abc)	Tlv(abc)	
		Ttcc(abc)		
		Ttc(abc)		
		af		

Table 2.2. Summary of the Shear Strength Groups for the Calabasas Quadrangle.

Adverse Bedding Conditions

Adverse bedding conditions are an important consideration in slope stability analyses. Adverse bedding conditions occur where the dip direction of bedded sedimentary rocks is roughly the same as the slope aspect, and where the dip magnitude is less than the slope gradient. Under these conditions, landslides can slip along bedding surfaces due to a lack of lateral support.

To account for adverse bedding in our slope stability evaluation, we used geologic structural data in combination with digital terrain data to identify areas with potentially adverse bedding, using methods similar to those of Brabb (1983). The structural data, derived from the geologic map database, was used to categorize areas of common bedding dip direction and magnitude. The dip direction was then compared to the slope aspect and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude was less than or equal to the slope gradient category but greater than 25% (4:1 slope), the area was marked as a potential adverse bedding area.

The formations, which contain interbedded sandstone and shale, were subdivided based on shear strength differences between coarse-grained (higher strength) and fine-grained (lower strength) lithologies. Shear strength values for the fine- and coarse-grained lithologies were then applied to areas of favorable and adverse bedding orientation, which were determined from structural and terrain data as discussed above. It was assumed that coarse-grained material (higher strength) dominates where bedding dips into a slope (favorable bedding) while fine-grained (lower strength) material dominates where bedding dips out of a slope (adverse bedding). The geologic material strength map was modified by assigning the lower, fine-grained shear strength values to areas where potential adverse bedding conditions were identified. The favorable and adverse bedding shear strength parameters for the formations are included in Table 2.1.

Existing Landslides

The strength characteristics of existing landslides (Qls) must be based on tests of the materials along the landslide slip surface. Ideally, shear tests of slip surfaces formed in each mapped geologic unit would be used. However, this amount of information is rarely available, and for the preparation of the earthquake-induced landslide zone map it has been assumed that all landslides within the quadrangle have the same slip surface strength parameters. We collect and use primarily "residual" strength parameters from laboratory tests of slip surface materials tested in direct shear or ring shear test equipment. Back-calculated strength parameters, if the calculations appear to have been performed appropriately, have also been used.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity." For the Calabasas Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.6 to 7.2
Modal Distance:	5 to 13 km
PGA:	0.42 to 0.65 g

The strong-motion record selected for the slope stability analysis in the Calabasas Quadrangle was the Channel 3 (north 35 degrees east horizontal component) University of Southern California Station # 14 recording from the magnitude 6.7 Northridge earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a peak ground acceleration (PGA) of 0.59 g. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

The design strong-motion record was used to develop a relationship between landslide displacement and yield acceleration (a_y), defined as the earthquake horizontal ground acceleration above which landslide displacements take place. This relationship was prepared by integrating the design strong-motion record twice for a given acceleration value to find the corresponding displacement, and the process was repeated for a range of acceleration values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for the design strong-motion record. This curve provides the required link between anticipated earthquake shaking and

estimates of displacement for different combinations of geologic materials and slope gradient, as described in the Slope Stability Analysis section below.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm were used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and a DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant in the Calabasas Quadrangle.

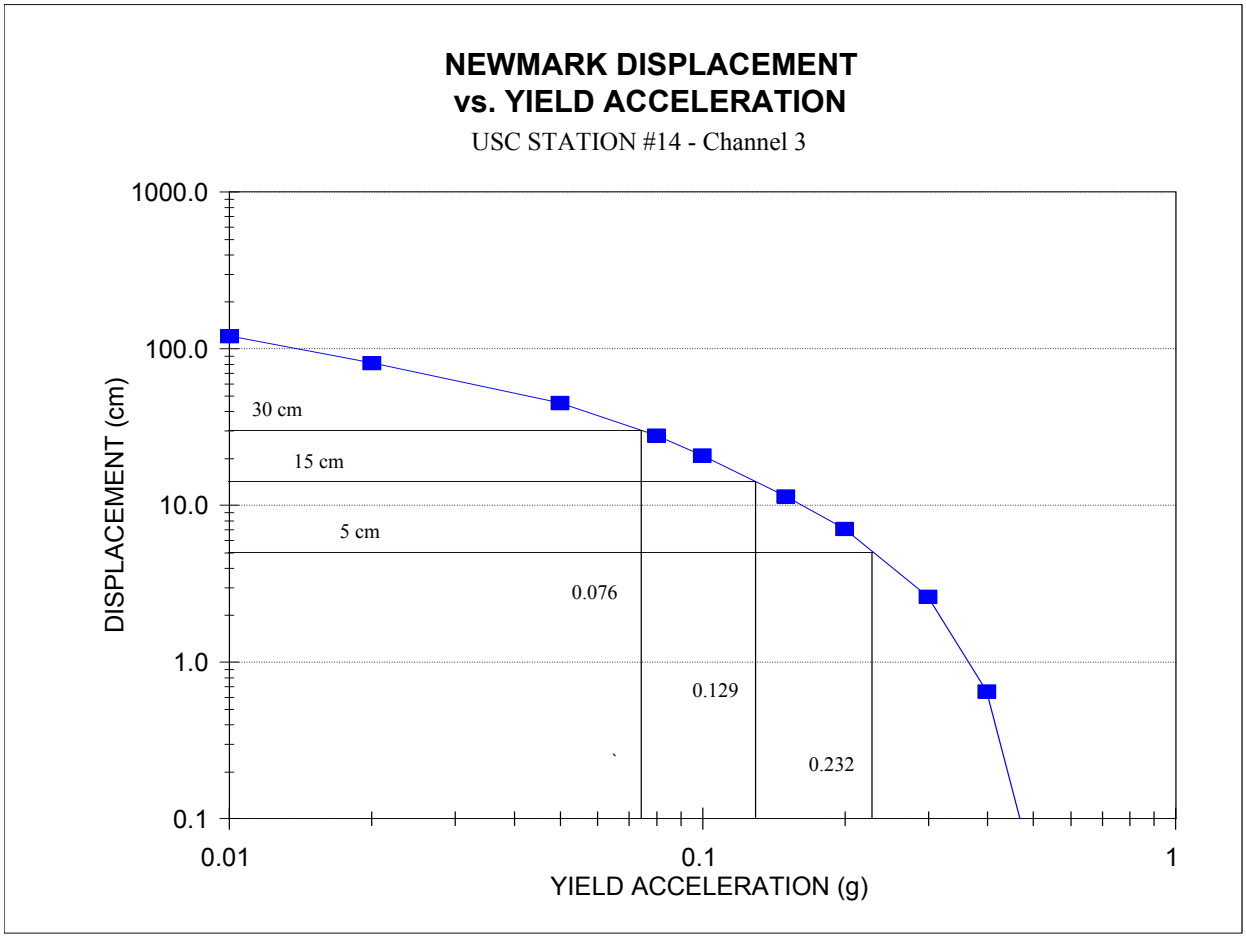

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the USC Station # 14 Strong-Motion Record from the 17 January 1994 Northridge, California Earthquake.

Slope Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.076g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned (H on Table 2.3)

2. If the calculated yield acceleration fell between 0.076g and 0.129g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned (M on Table 2.3)

3. If the calculated yield acceleration fell between 0.129g and 0.232g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned (L on Table 2.3)

4. If the calculated yield acceleration was greater than 0.232g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned (VL on Table 2.3)

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

CALABASAS QUADRANGLE
HAZARD POTENTIAL MATRIX

Geologic Material Group	MEAN PHI	SLOPE CATEGORY I 0-5	II 6-13	III 14-23	IV 24-28	V 29-39	VI 40-45	VII 46-49	VIII 50-56	IX 57-65	X > 65	percent
1	37	VL	VL	VL	VL	VL	VL	VL	L	M	H	
2	33	VL	VL	VL	VL	VL	L	L	M	H	H	
3	28	VL	VL	VL	VL	L	M	H	H	H	H	
4	20	VL	VL	L	M	H	H	H	H	H	H	
5	10	L	H	H	H	H	H	H	H	H	H	

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Calabasas Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone. H = High, M = Moderate, L = Low, VL = Very Low.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (DOC, 2000). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.

2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail in the following sections.

Existing Landslides

Existing landslides typically consist of disrupted soils and rock materials that are generally weaker than adjacent undisturbed rock and soil materials. Previous studies

indicate that existing landslides can be reactivated by earthquake movements (Keefer, 1984). Earthquake-triggered movement of existing landslides is most pronounced in steep head scarp areas and at the toe of existing landslide deposits. Although reactivation of deep-seated landslide deposits is less common (Keefer, 1984), a significant number of deep-seated landslide movements have occurred during, or soon after, several recent earthquakes. Based on these observations, all existing landslides with a definite or probable confidence rating are included within the earthquake-induced landslide hazard zone.

No earthquake-triggered landslides had been identified in the Calabasas Quadrangle prior to the Northridge earthquake. The Northridge earthquake caused a number of relatively small, shallow slope failures in the Calabasas Quadrangle (Harp and Jibson, 1995). Landslides attributed to the Northridge earthquake covered approximately 104 acres of land in the quadrangle, which is less than 1/2 of 1 percent of the total area covered by the map. Of the area covered by these Northridge earthquake landslides, 86% falls within the area of the hazard zone based on a computer comparison of the zone map and the Harp and Jibson (1995) inventory.

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by DMG (McCrink and Real, 1996), it has been concluded that earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicate earthquake displacements of 5 centimeters or greater. Areas with a Very Low hazard potential, indicating less than 5 centimeters displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 5 is included for all slope gradient categories. (Note: Geologic Strength Group 5 includes all mappable landslides with a definite or probable confidence rating).

2. Geologic Strength Group 4 is included for all slopes steeper than 14 percent.

3. Geologic Strength Group 3 is included for all slopes steeper than 29 percent.

4. Geologic Strength Group 2 is included for all slopes steeper than 40 percent.

5. Geologic Strength Group 1 is included for all slopes greater than 50 percent.

This results in 27 percent of the quadrangle lying within the earthquake-induced landslide hazard zone for the Calabasas Quadrangle.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project. Geologic material strength data were collected at the City of Calabasas with the assistance of Donald Kowalewsky, at the Los Angeles County Department of Public Works with the assistance of Robert Larson, Charles Nestle, and Mike Montgomery, at the City of Los Angeles with the assistance of Nicki Girmay, and at the Ventura County Public Works Agency with the assistance of James O'Tousa. Digital terrain data were provided by Randy Jibson of the U.S. Geological Survey (USGS DEM), and JPL and Calgis, Inc. (Radar DEM). Technical review of the methodology was provided by Bruce Clark, Randy Jibson, Robert Larson, Scott Lindvall, and J. David Rogers, who are members of the State Mining and Geology Board's Seismic Hazards Mapping Act Advisory Committee Landslides Working Group. At DMG, special thanks to Bob Moskovitz, Teri McGuire, Barbara Wanish, and Scott Shepherd for their Geographic Information System operations support, and to Joy Arthur for designing and plotting the graphic displays associated with the hazard zone map and this report.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
City of Calabasas, Planning Department	**41**
Los Angeles City, Department of Building and Safety	**142**
Los Angeles County Department of Public Works, Materials Engineering Division	**146**
Ventura County	**21**
Division of Mines and Geology, Environmental Impact Report files.	**23**
Total number of tests used to characterize the units in the Calabasas Quadrangle	**373**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Calabasas 7.5-Minute Quadrangle, Los Angeles and Ventura Counties, California

By

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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided

herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (California Department of Conservation, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.conservation.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

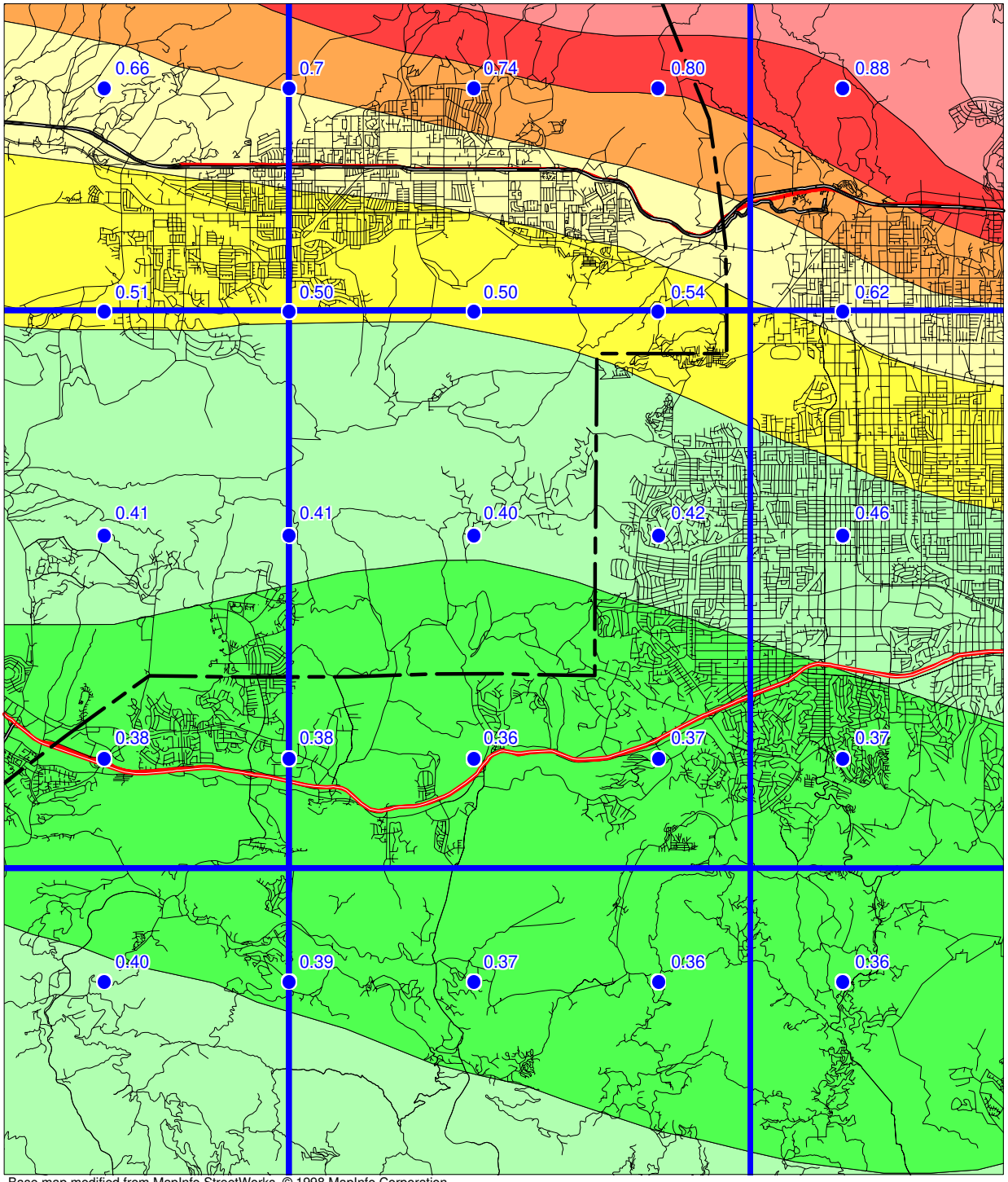
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent

CALABASAS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

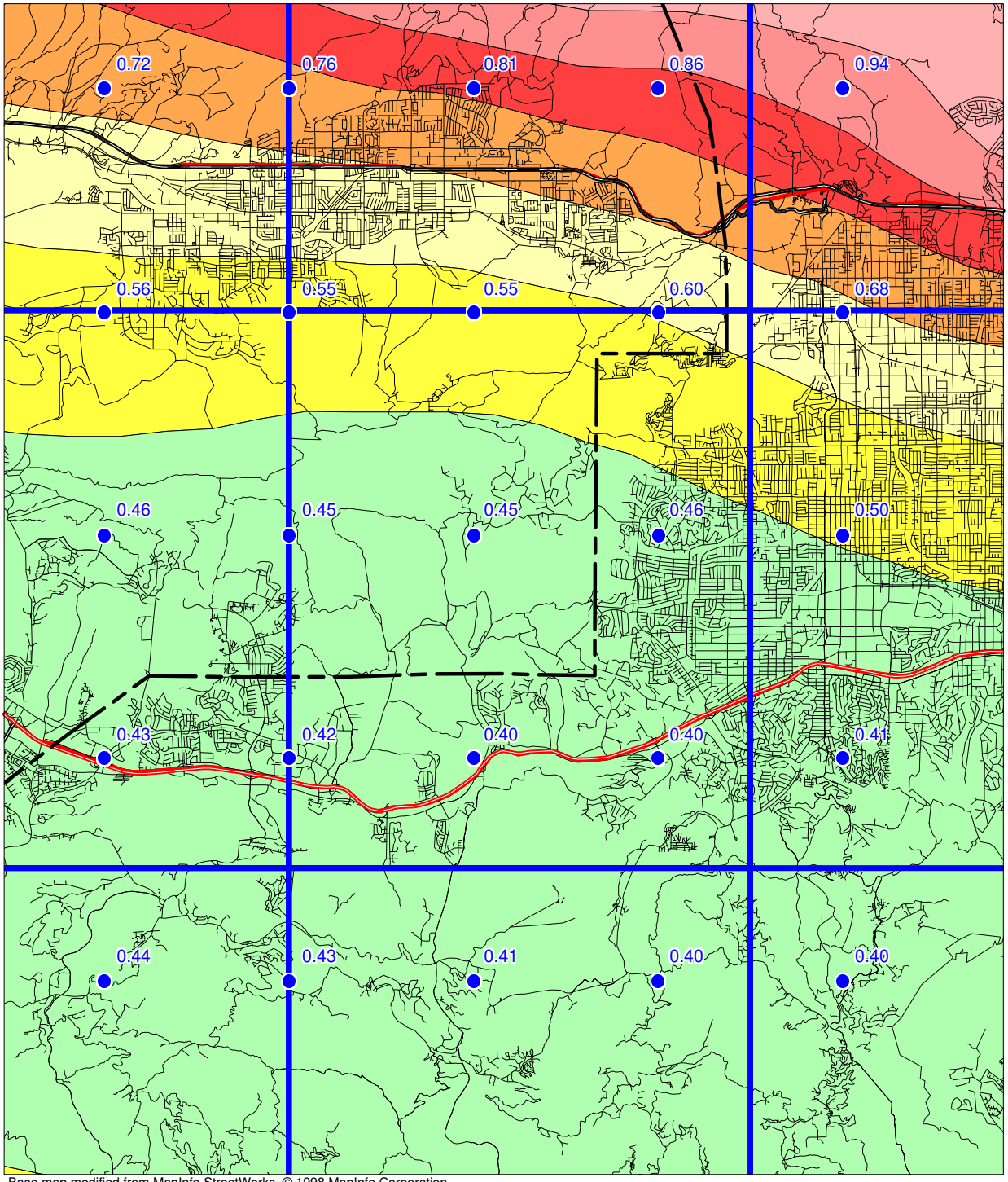
Figure 3.1

CALABASAS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

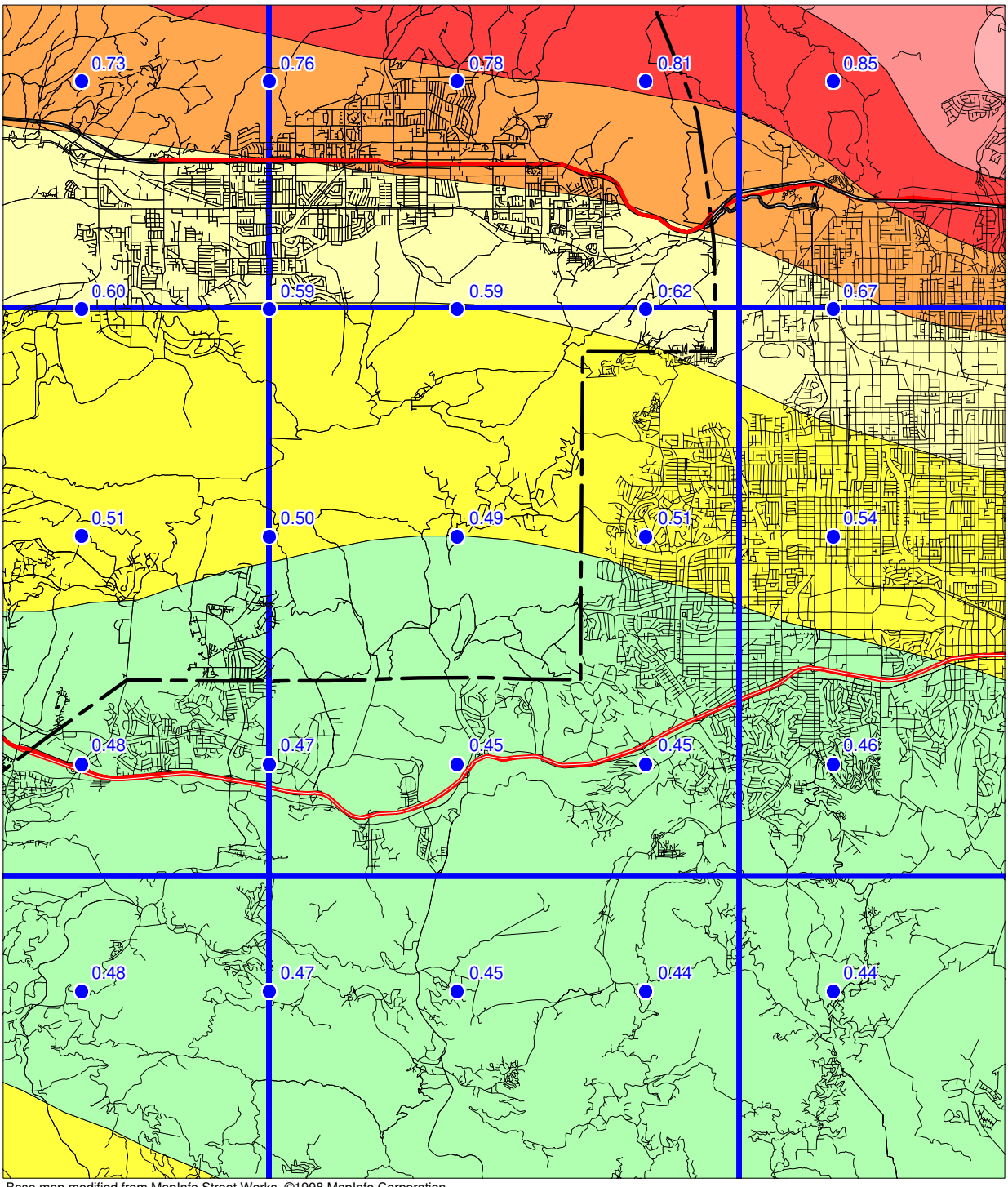
Figure 3.2

CALABASAS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5
Kilometers

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Figure 3.3

quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the "simplified Seed-Idriss method" of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a "magnitude-weighted" ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

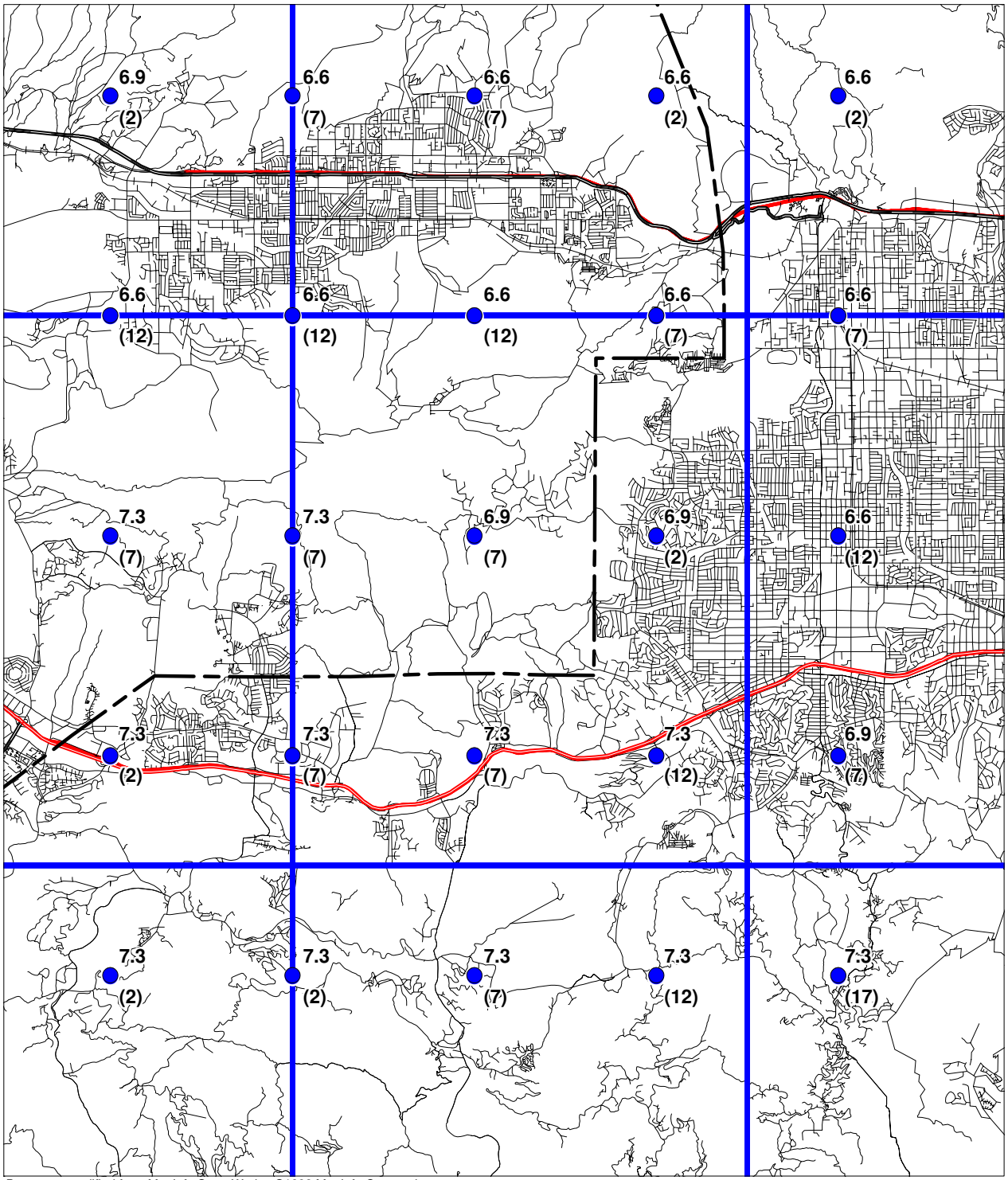
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

CALABASAS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

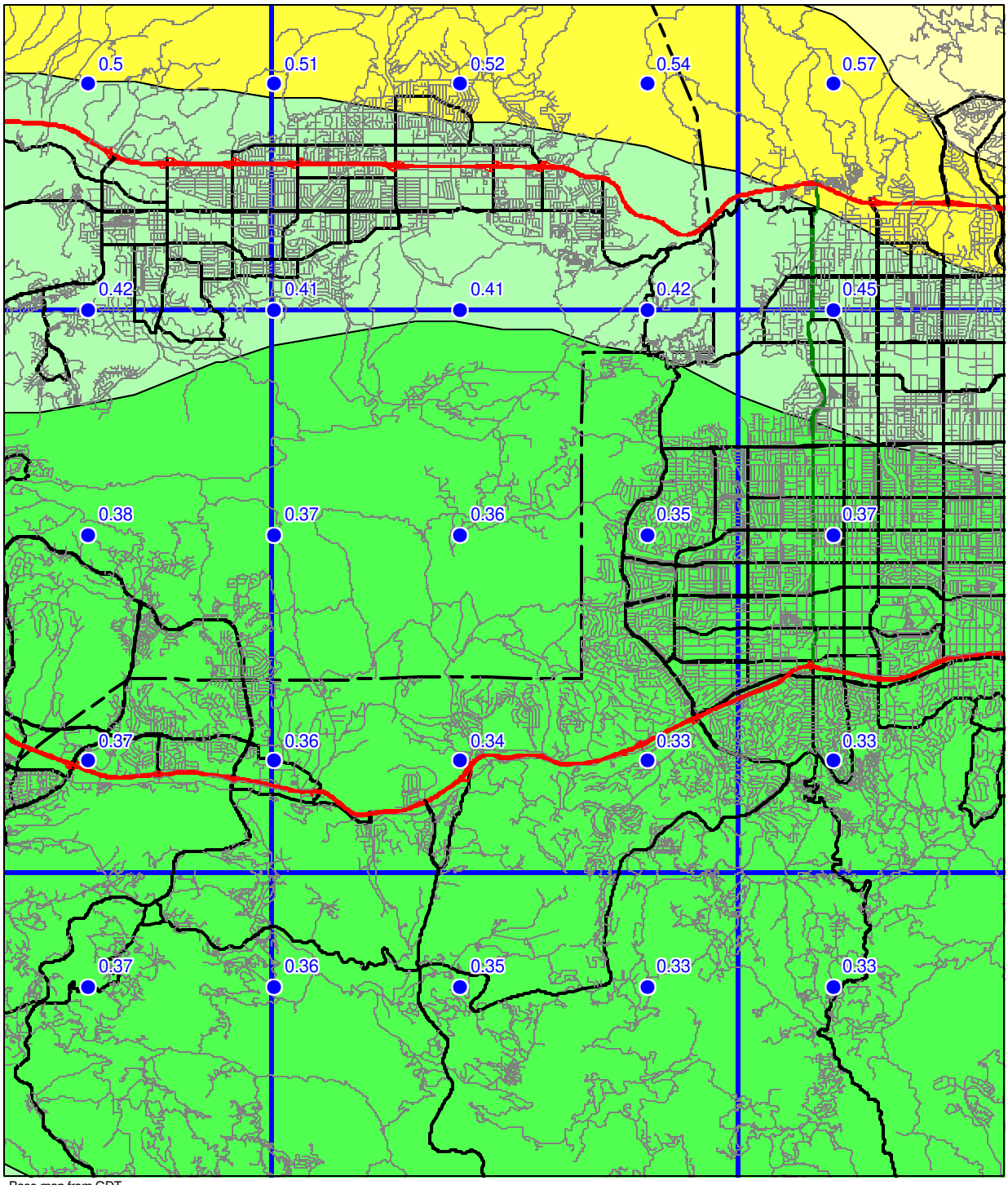
Figure 3.4

CALABASAS 7.5-MINUTE QUADRANGLE AND PORTIONS OF
ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g)
FOR ALLUVIUM

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

Figure 3.5

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the

recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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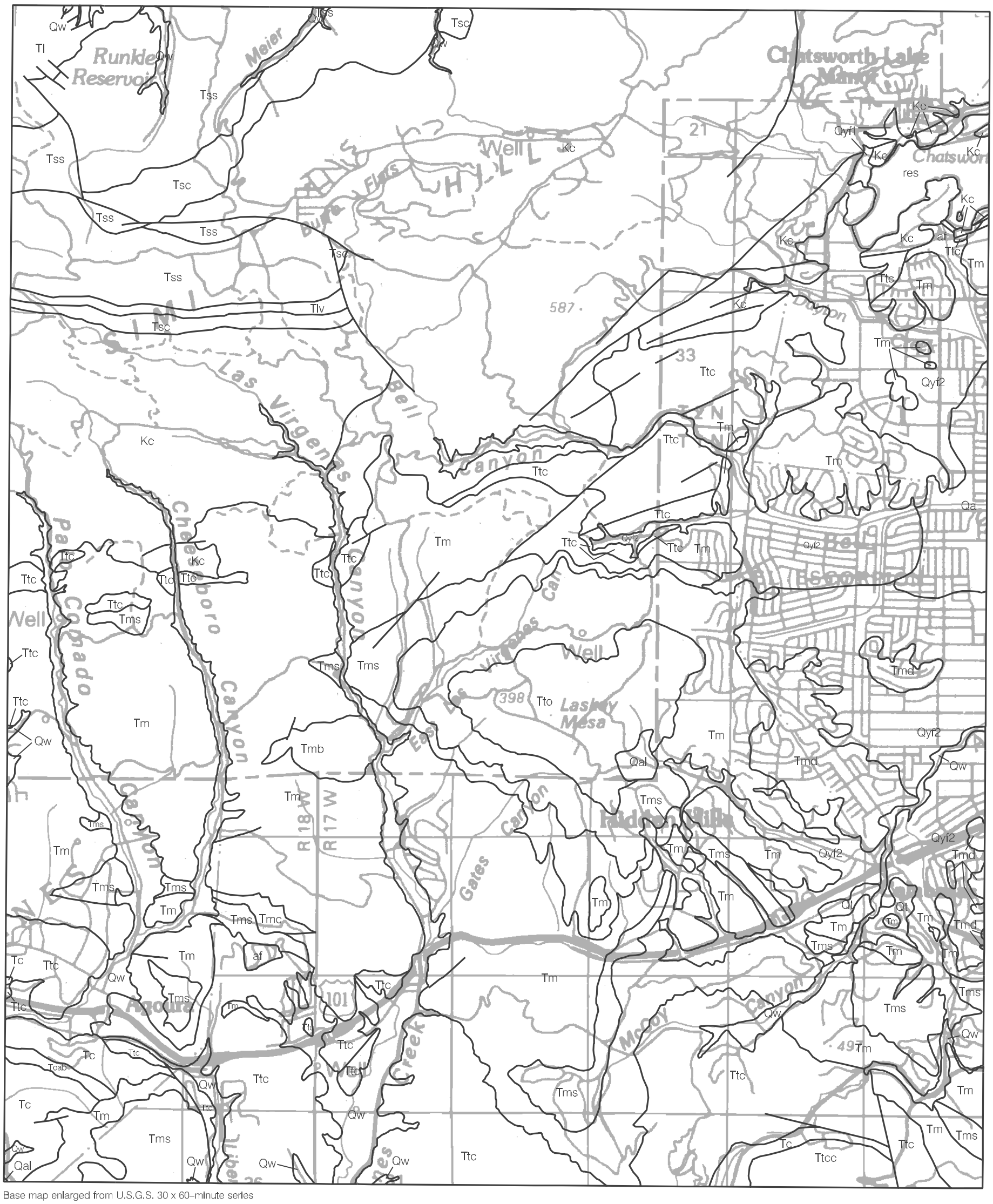


Plate 1.1 Quaternary Geologic Map of the Calabasas 7.5-minute Quadrangle, California.

Plate 1.1 Quaternary Geologic Map of the Burbank Quadrangle.
See Geologic Conditions section in report for descriptions of the units.

res = reservoir.

ONE MILE
SCALE

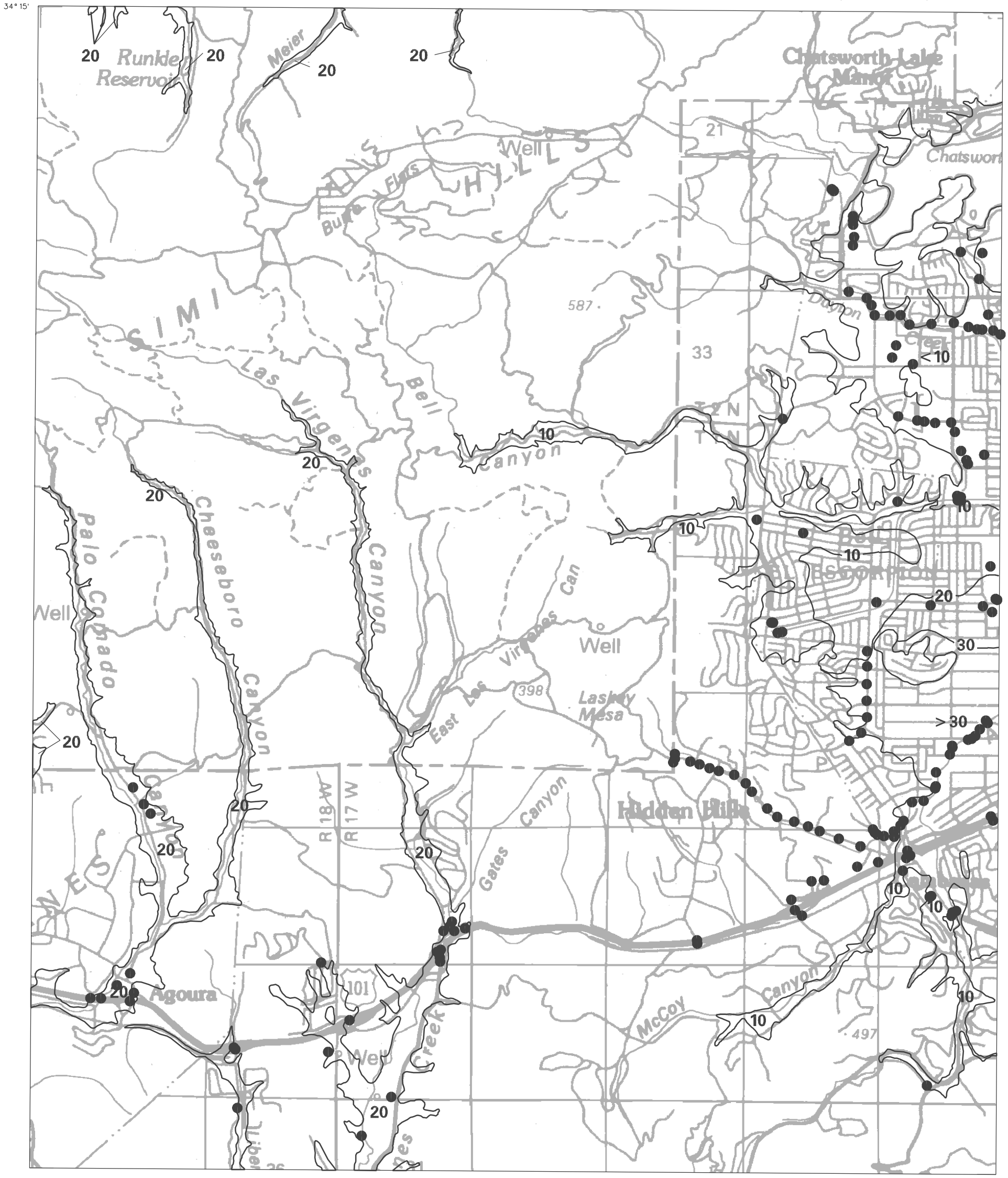


Plate 1.2 Depth to historically high ground water, and locations of boreholes used in this study, Calabasas 7.5-minute Quadrangle, California

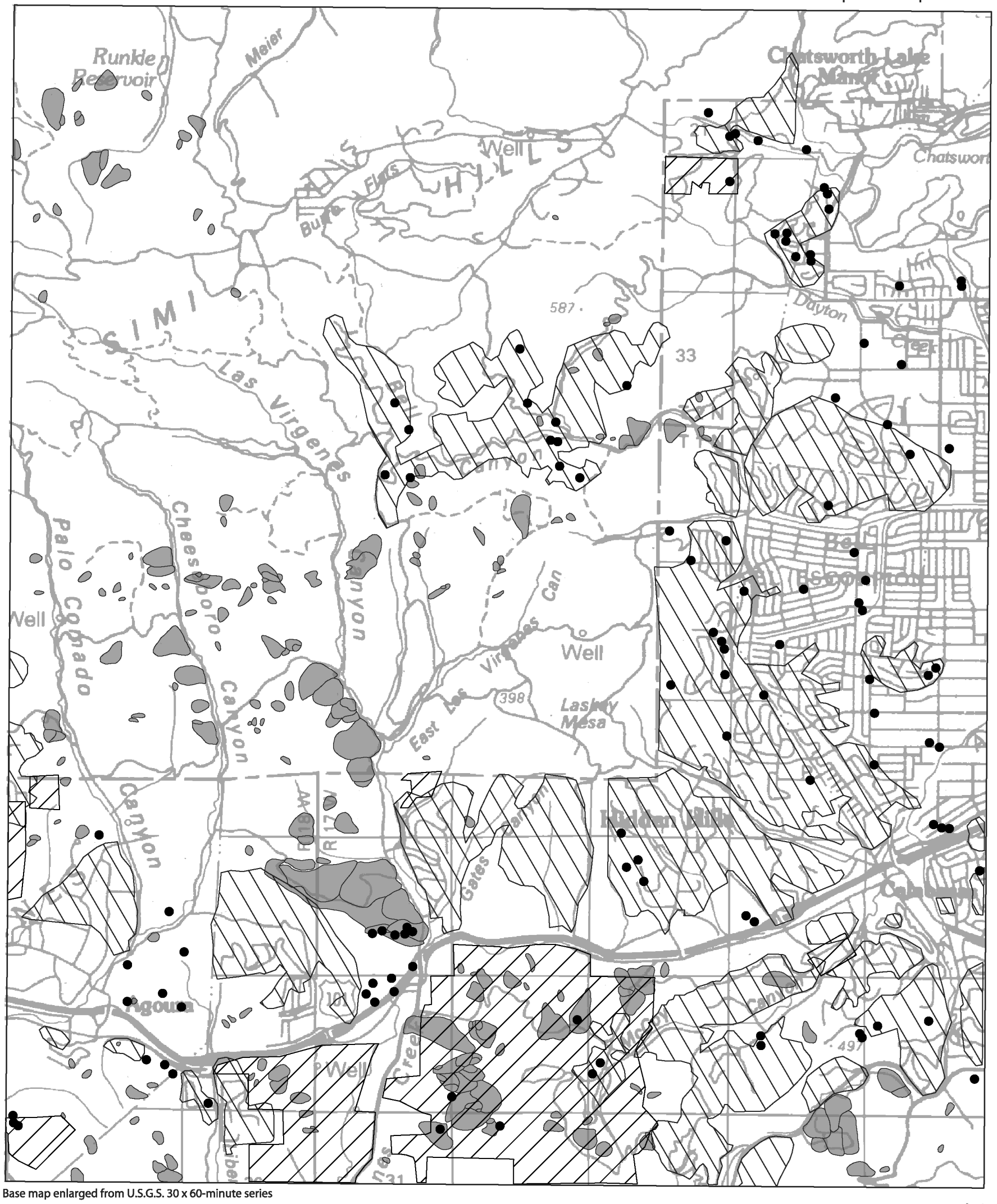
● Borehole Site

30 Depth to ground water in feet

ONE MILE
SCALE

118°45'

34°15'



Base map enlarged from U.S.G.S. 30 x 60-minute series

34°07'30"

118°37'30"

Plate 2.1 Landslide inventory, Shear Test Sample Locations, and Areas of Significant Grading, Calabasas Quadrangle.

● shear test sample location

landslide

areas of significant grading

tract report with multiple borings

ONE MILE

SCALE